Loop Heat Pipe Manufacturing via DMLS for CubeSAT Applications, Phase II

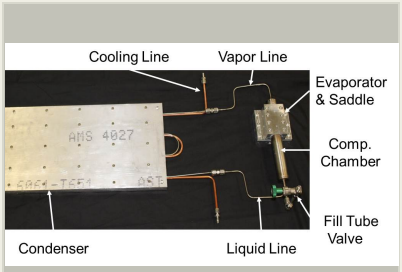
Completed Technology Project (2017 - 2021)

Project Introduction

Advanced Cooling Technologies, Inc. (ACT) proposes to develop a low-cost Loop Heat Pipe (LHP) evaporator using a technique known as Direct Metal Laser Sintering (DMLS), otherwise known as 3D printing, to produce low-cost LHPs to be used in CubeSat and SmallSat applications. The wick structure in an LHP assumes the role of a pump in a standard loop, pumping liquid from the lower pressure condenser to the higher pressure evaporator by capillary forces. The overall thermal performance of the system is therefore highly dependent on the in-situ characteristics of the wick structure. Current LHP wick manufacturing and installation processes are cumbersome, labor intensive, and suffer from a low yield rate. It is estimated that the cost to produce an LHP evaporator, including the attachment of the bayonet, secondary wick and compensation chamber, accounts for approximately 75% of the total system's manufacturing cost. By 3D printing an evaporator envelope with an integral porous primary wick structure, the overall complexity and cost of the design can be significantly reduced. The Phase I program was fully successful. In Phase I, an LHP with a DMLS evaporator was built using ammonia as the fluid, and carried the predicted 45 W. The overall technical objective of the Phase II program will be to design, build, and test a complete LHP thermal management system for a CubeSat. Phase II work will include further optimization of the LHP manufacturing parameters, and the development of advanced wick structures such as a graded wick design. The deliverables at the end of the Phase II will include an LHP that has been thermal vacuum tested, and a second LHP flight unit with ethanol working fluid, that can be tested at NASA's option on the ISS.

Anticipated Benefits

Ammonia and propylene LHPs are currently used in most NASA and commercial satellites. In comparison with Constant Conductance Heat Pipes (CCHPs), they carry much higher powers (1 kW vs. 100 W) over longer distances (10 m vs. 2-3 m). They also are better suited for ground testability. An LHP can operate with the evaporator 2 meters above the condenser, versus 2.5 mm for a CCHP. Their main drawback is that they are two orders of magnitude more expensive to fabricate and test than CCHPs. Fabricating, machining, and inserting the primary and secondary wicks into the pump is the bulk of the fabrication expense (The remainder of the LHP is just plumbing). The first benefit of the proposed evaporator/wick fabrication will be a significant reduction in cost of LHPs supplied to NASA. A second benefit of reduced costs it that LHPs will be much more attractive for the smaller satellites, such as SmallSat and CubeSat, that NASA is now considering for future missions. The overall budget for these satellites is severely constrained when compared to the larger satellites that NASA has fabricated in the past. LHPs have not been considered in the past for these small satellites, partially due to their high cost. The reduced fabrication costs will allow ACT to fabricate smaller LHPs for these smaller satellites, at a price that is acceptable with



Loop Heat Pipe Manufacturing via DMLS for CubeSAT Applications, Phase II Briefing Chart Image

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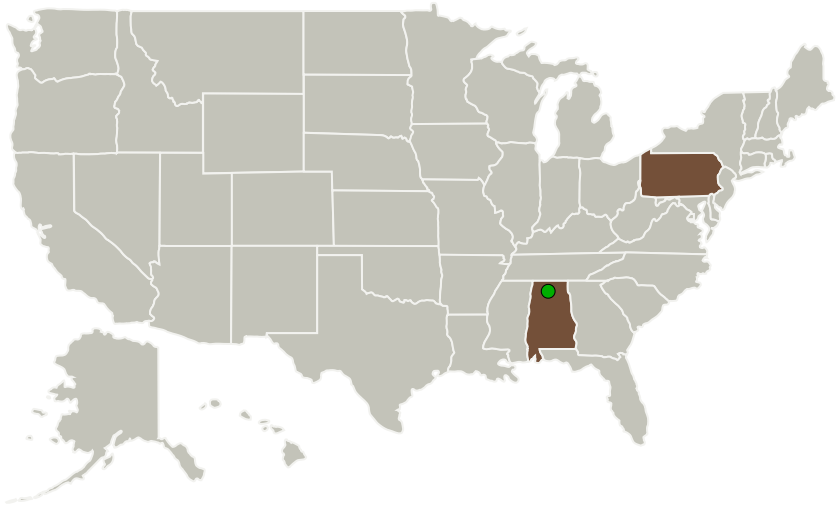
their smaller budgets.ACT is one of only two companies in the United States that sells heat pipes, Variable Conductance Heat Pipes (VCHPs), and LHPs to the government and commercial customers for spacecraft thermal control. The benefits for the Air Force are similar to the benefits for NASA, both for today?s spacecraft, and for smaller satellites in the future. The commercial communications satellite market is the current primary market for LHPs. For example, one prime uses 5 to 6 LHPs on each satellite, and would also benefit from reduced costs. Finally, Universities are able to fabricate their own CubeSats for research in space; however, their budgets are much too limited to allow them to use LHPs as a thermal control tool. In addition, these SmallSats have no need for the high powers and long lengths of current LHPs. They could benefit from small size LHPs, if the cost can be significantly reduced. ACT plans to explore this market, after satisfying the higher end government and commercial markets.

Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
Advanced Cooling Technologies, Inc.	Lead Organization	Industry	Lancaster, Pennsylvania
Marshall Space Flight Center(MSFC)	Supporting Organization	NASA Center	Huntsville, Alabama

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Organization:

Advanced Cooling Technologies, Inc.

Responsible Program:

Small Business Innovation Research/Small Business Tech Transfer

Project Management

Program Director:

Jason L Kessler

Program Manager:

Carlos Torrez

Project Managers:

Gwenevere L Jasper
Jeffery T Farmer

Principal Investigator:

William Anderson

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Primary U.S. Work Locations	
Alabama	Pennsylvania

Project Transitions

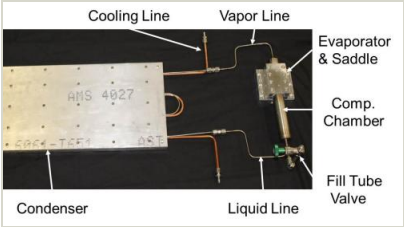
May 2017: Project Start

June 2021: Closed out

Closeout Documentation:

- Final Summary Chart PDF*(https://techport.nasa.gov/file/141119)*

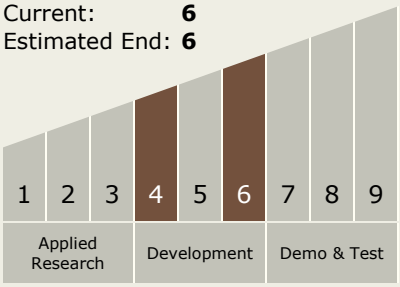
Images



Briefing Chart Image
Loop Heat Pipe Manufacturing via DMLS for CubeSAT Applications, Phase II Briefing Chart Image *(https://techport.nasa.gov/image/132212)*

Technology Maturity (TRL)

Start: **4**
Current: **6**
Estimated End: **6**



Target Destinations

The Sun, Earth, The Moon, Mars, Others Inside the Solar System, Outside the Solar System